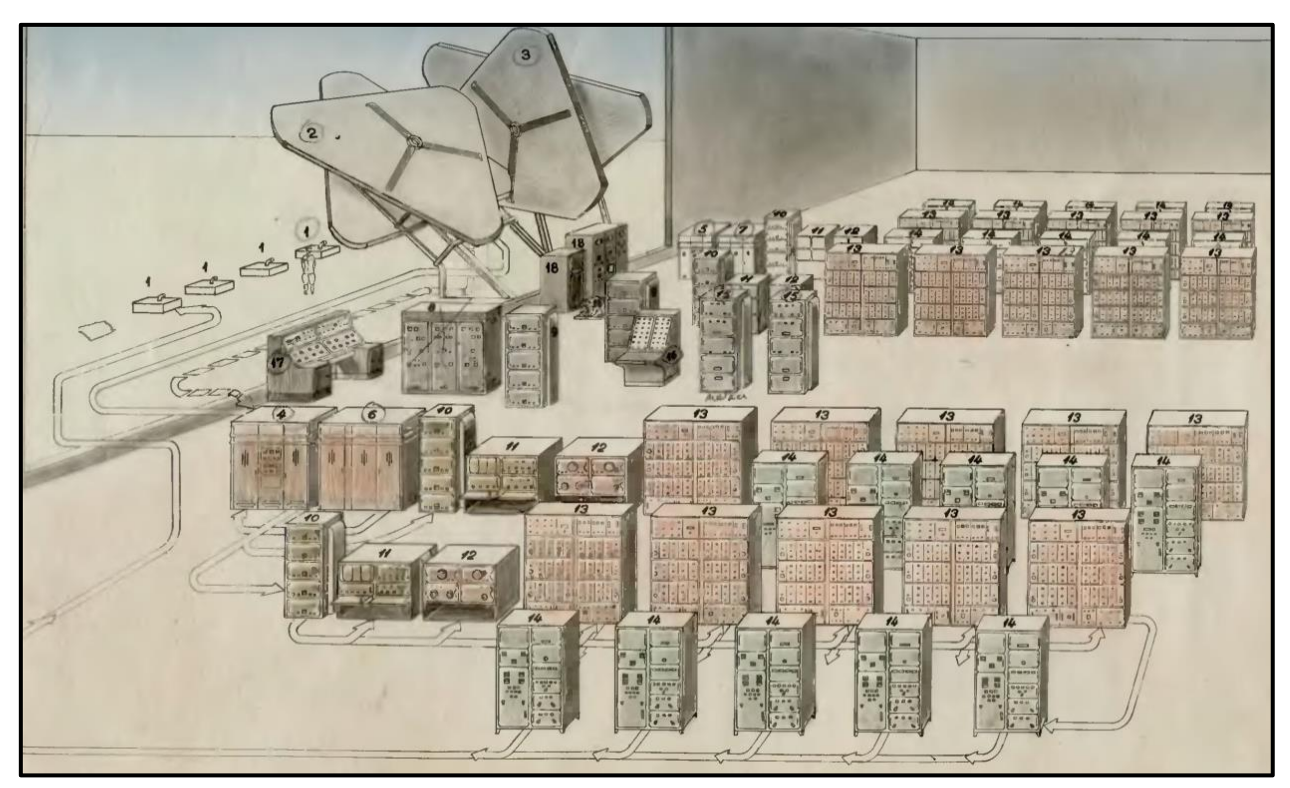
The S-25 Berkut[1]

The first guided missiles system of the Soviet Union[2] was the S-25 Berkut. The development and the need of the system induced by the experiences of strategic bombing of the World War II, especially the two nuclear bomb attack against Japan. The Soviet developers had the same conclusion as the US scientist, because of the limitation of air defense guns against more and more faster and higher flying bombers is not possible to defend cities within reasonable costs with desired efficiency. The development of the Berkut started in August of 1950; its name came from the name of the lead designers. (Sergei L. Beria, the son of the Lavrentiy Pavlovich Beria, the leader of the NKVD/KGB and Pavel N. Kuksenko.)

The S-25 was one of a kind and a very expensive SAM system, its many features and technical solutions were unique, later developed SAM system did not followed and improved the concept of S-25. The system was totally static and for later SAM system at least had to be deployable, at least some mobility was a design requirement.

The Berkut regardless was among the first SAMs in the world it had multiple target channels, but this feature achieved by "brute force" rather than elegant technical solutions as later achieved with S-300 (SA-10A). The brute force approach had a strong impact both on the size on the elements of the Berkut system as well as on its cost. The main elements of the S-25 were the followings:

- A-100B/D (Gage) early warning radar, 10 cm wavelength
- B-200 (Yo-Yo) fire control radar system, 10 cm wavelength
- V-300 (Guild) missile (with different missile subtypes after upgrades of the system)

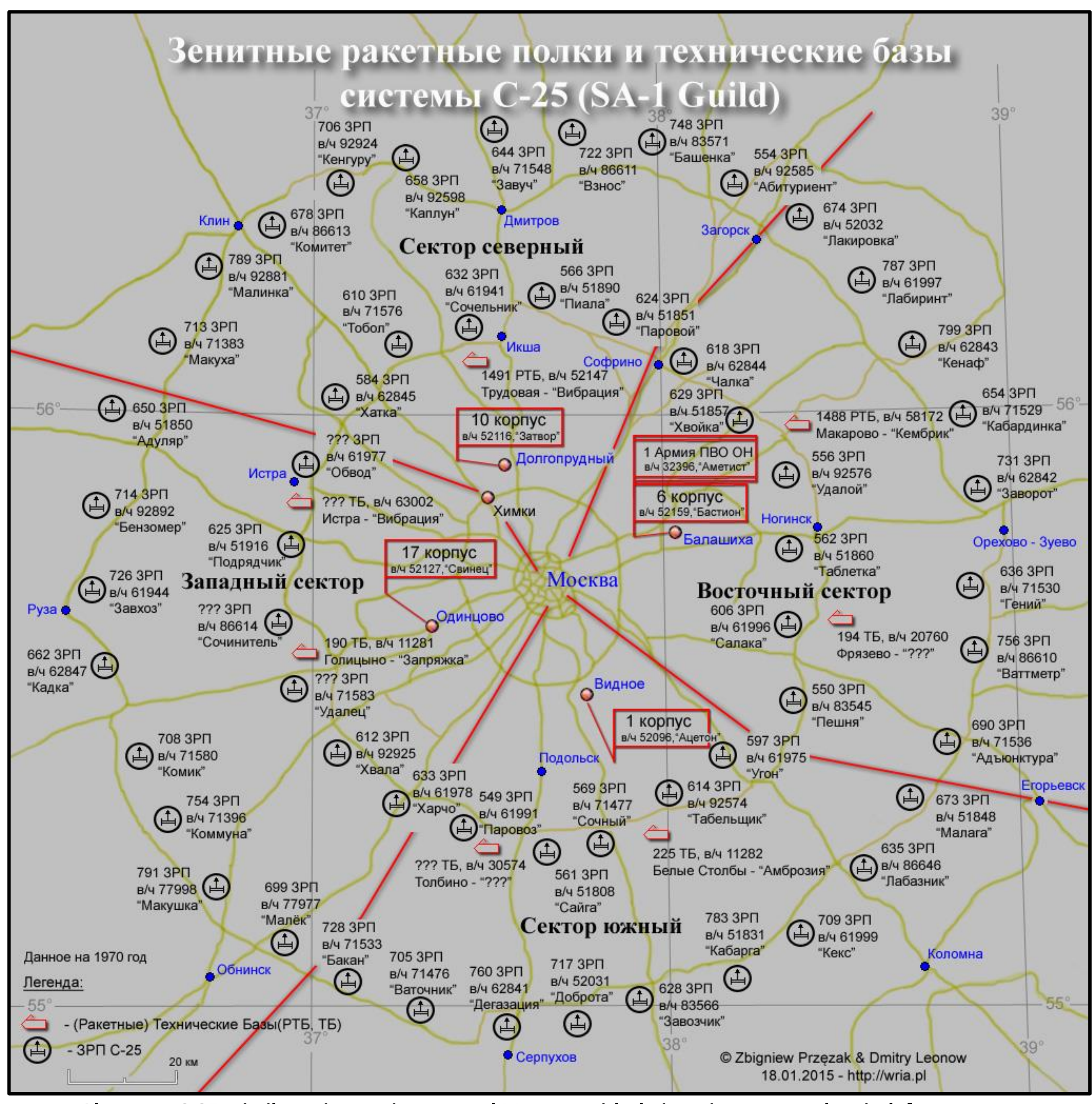


The equipment of the Berkut regiment in the bunker, the cabinets were 1-2 men size big. The drawing demonstrates well why the Berkut was a totally static system.

[1] *http://infowsparcie.net/wria/o_autorze/pzr_s25berkut.html Google translate does a good job to translate the source into English, only the diagrams and images cannot be translated.*

[2] *Depending on source and how the IOC is treated was a very strong competition with the American Nike Ajax System to be the first operational SAM system in the world.*

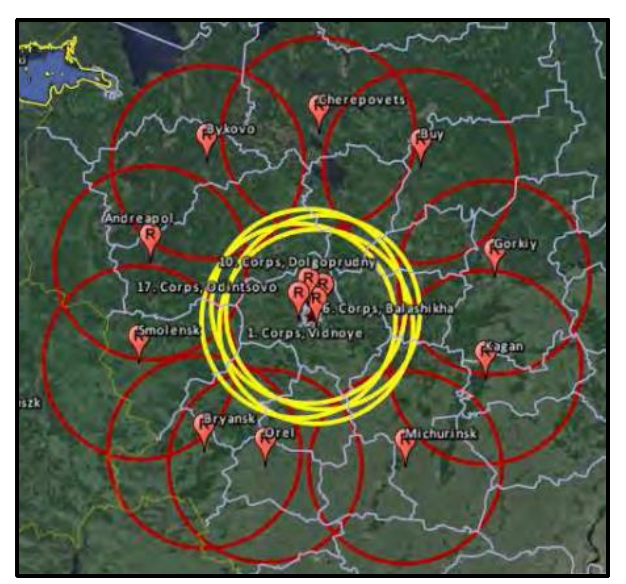
The S-25 Berkut was built around Moscow, formed two concentric defense rings which protected the capital with equal strength from all directions against the strategic bombers of the SAC.[3] The long range early warning radars were built about 400 km from city center with about 200 km detection range against bombers. To get full coverage 10 A-100D radars were needed and 4 more A-100B was installed closer to Moscow to monitor the nearby airspace of Moscow.



Above are S-25 missile regiment sites around Moscow with their assignment to the air defense corps.

The SAM sites around Moscow – each SAM site was a single missile regiment – were part of the two concentric SAM rings. The outer ring was about 85-90 km distance from the city, the inner was about 45-50 km. The outer ring consisted 34 regiments, the inner 22 regiments; they were assigned into 4 different SAM division corps (10th, 6th, 1st and 17th.)

[3] *Strategic Air Command*





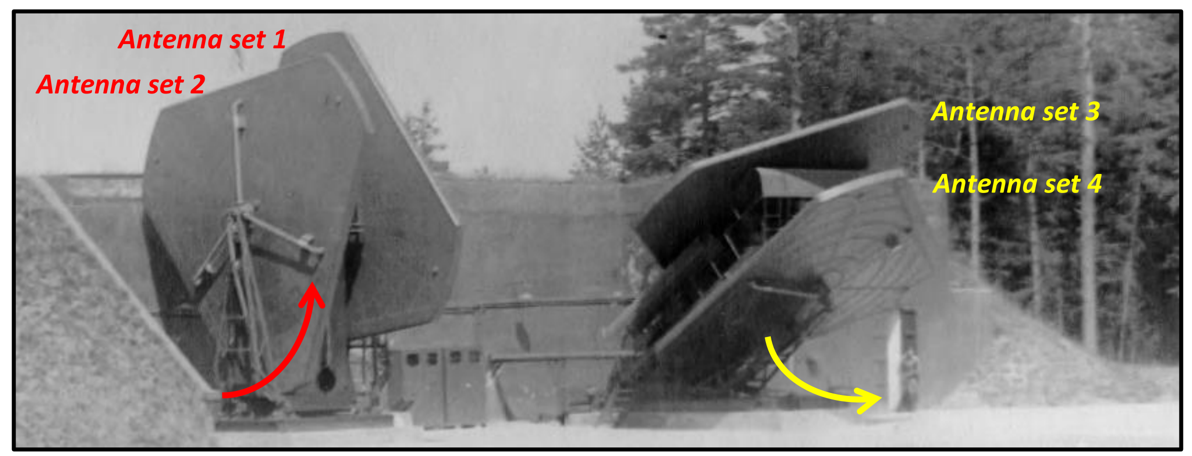
Above left are the location of 10 A-100D radars (red circles) and 4 A-100B radars (yellow circles), above right is the Gage radar.

The concrete foundations, the roads and other civil works for the SAM system were built around Leningrad (today is St. Petersburg) either but because of financial issues the cheaper SA-75/S-75 and S-125 SAMs were deployed later and S-25 was not built for the second most important Soviet city. The road network of the Berkut around Moscow was about 1000 km long, the hardened bunkers and other building costs were about half (!) of the total cost of Berkut, which meant a put a huge stress on the economics of the Soviet Union in post World War era.

Not only because the infrastructural elements of the Berkut but the level of electronic industry of early '50s made it very expensive. The equipment of single regiment consisted about 13 000 vacuum tubes and initially the life span of these were very low, only about 500 hours. Only several years later could be this upgrade to about 3000 hours

About quarter of the cost were spent on radar and electronics.

(The total cost of the Berkut was 13 billion Rubles which in that time were counted in 1:1 USD parity.)



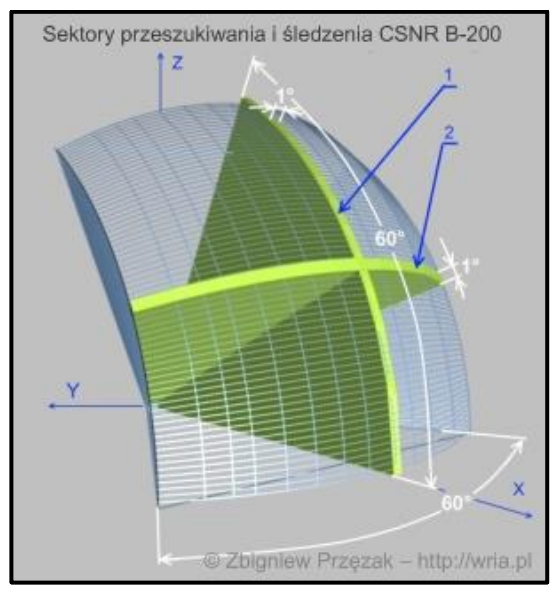
Above are the B-200 Yo-Yo fire control radars. The radar on left side scanned in elevation, on the right side in azimuth direction.

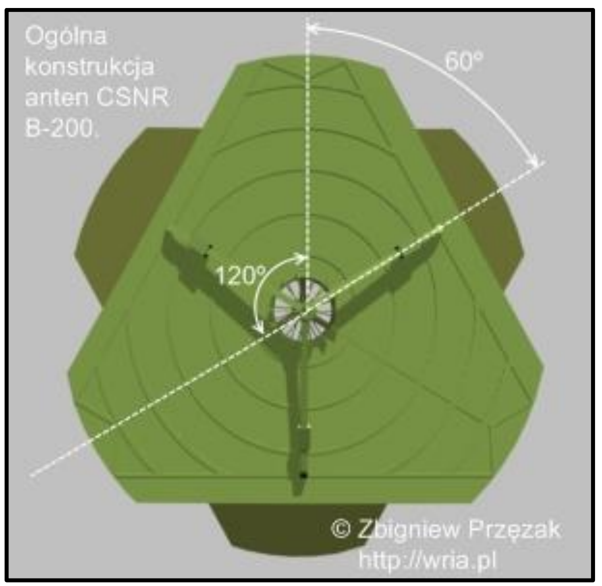
The pair Yo-Yo antenna system was very unique, it was the first TWS (track while scan) capable radar system in the world, it served search and fire control functions either. The rotating antennas sets scanned separately in azimuth (left-right, set 3&4) and elevation (up-down, set 1&2) directions. Both radar

structures had two rotating antenna sets to increase the scan/refresh rate. A single antenna set had 3 antennas; the emitters were positioned with 120 degree offset.

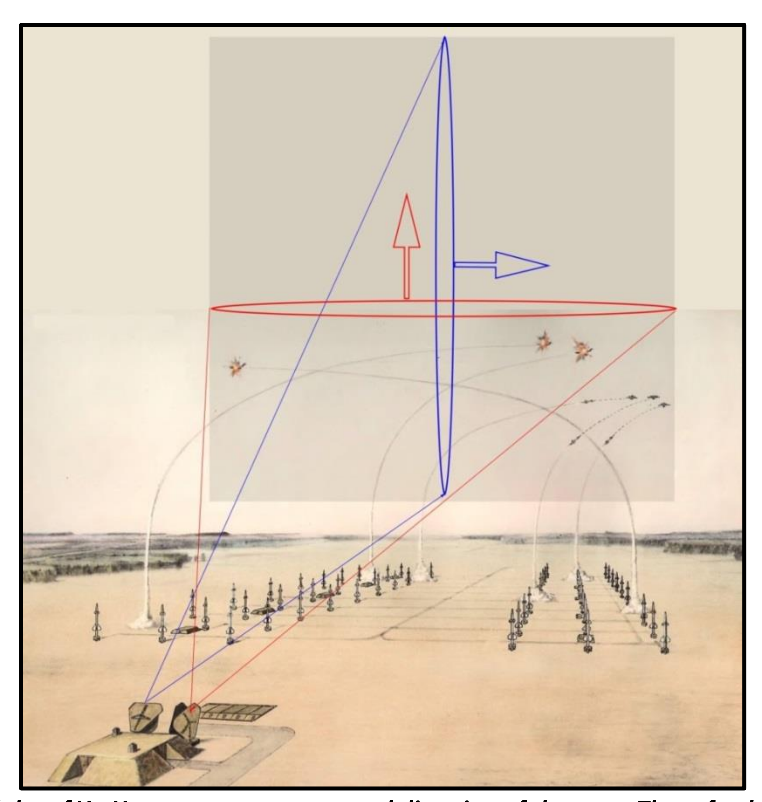
Each antenna (emitter) produced 1x60 degree lobe, the rotation of the antenna sets produced the spherical shell scan zone, see on the drawings below.

Each antenna sets speed were had 50 rounds/min, each antenna structures has two antenna sets and each set had 3 emitters, this meant 50x2x3 = 300 scan per minute in a 60x60 degree area. This provided the target data for missile guidance for all the 20 target channels. For comparison the later discussed SA-75/S-75 fire control radars provided only 10x10 or 7x7 degree area with similar scan rate for only a single target channel.





Above is the Yo-Yo antenna structure and the scan zone.



Above is the emitted lobe of Yo-Yo antenna structure and direction of the scan. The refresh rate of the Yo-yo was 300/minute (5/second), this supported the TWS capability.

A single S-75 Berkut regiment could guide 20 missiles against 20 targets (20 target and 20 missile channels) which even today's standards counting only these factors is a more than respectable capability not mentioning the early Cold War era where even in the middle of '70s every land based SAM systems had only a single target channel.

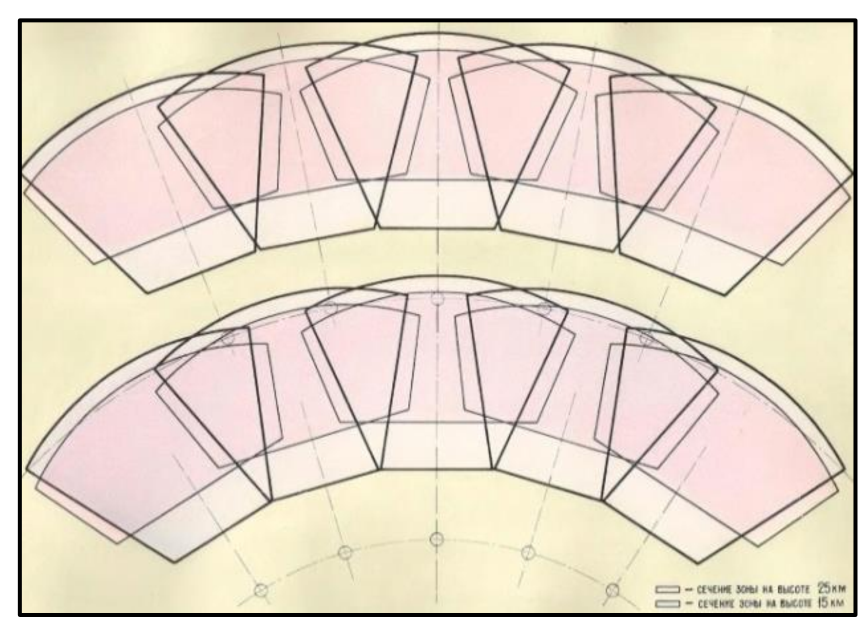
For a single SAM site (regiment) 60 V-300 missile were on launch stations. The missile was single stage, liquid fuel propelled with radio control guidance (RCG). The fuel of the missile was a very strong neurotoxin because of this the work on missiles could be done only in full chemical protection suite which made very difficult the maintenance and handling of the missiles. The cost of missiles represented about the final quarter of the total cost of the Berkut system. The capabilities the different subtype of missiles is in the chart below.

Missile type	***IOC***	***maximal range***	***maximal altitude***	***minimal altitude***
V-300 205	1953	30 km	25 km	5 km
V-300K 207A	1954	35 km	25 km	3 km
V-300K 215 (207T)	**1957**	**35 km**	**25 km**	**5 km**
V-300M 217M	1962	43 km	30 km	1.5km
V-300M 218 (217T)	**1964**	**43 km**	**30 km**	**6 km**
V-300M 5Ya25 (217MA)	1968	43 km	35 km	1.5 km
V-300M 5Ya25M (217MAM)	1975	43 km	35 km	0.5 km
V-300M 5Ya24 (219)	1980	46 km	35 km	0.5 km
V-300M 44N6 (5Ya24S)	**1980**	**46 km**	**35 km**	**3.5 km**

The missiles marked with red were equipped with nuclear warhead

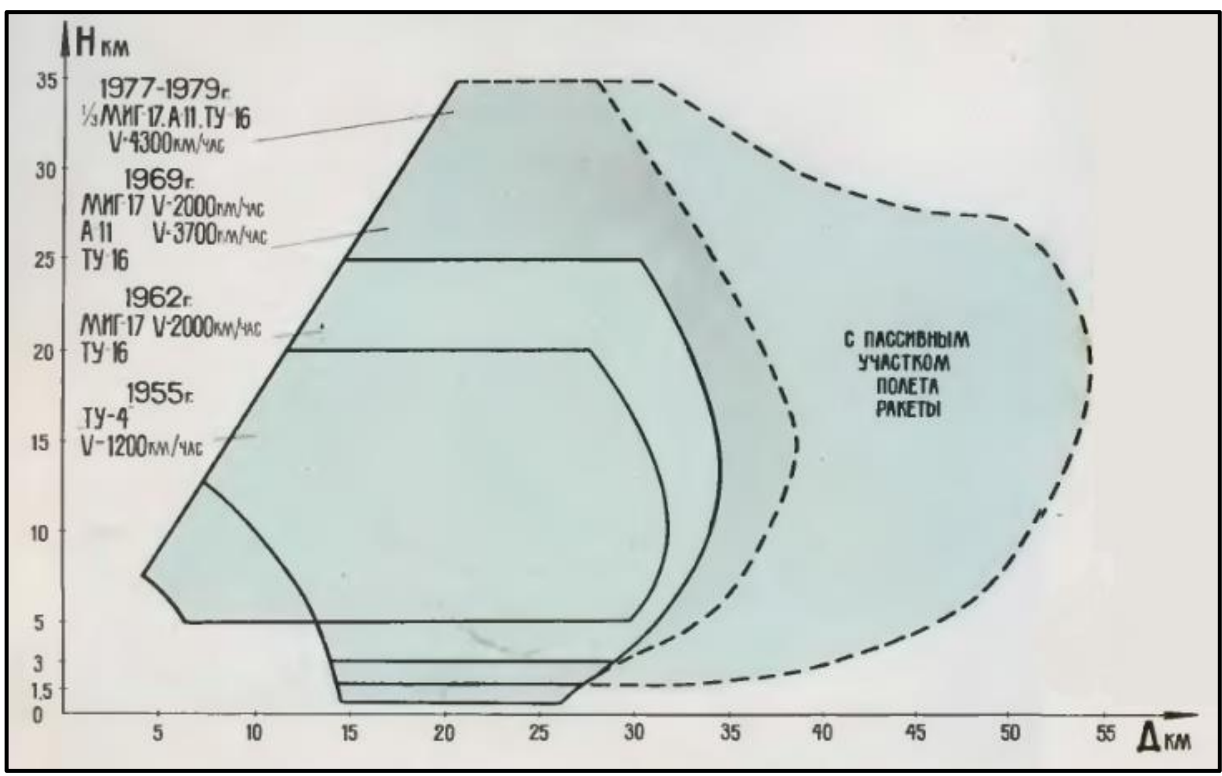
Checking the values chart above clearly shows Berkut was not designed against low flying targets, in the time this was not a design requirement because of the bombers of SAC was expected at 10 km or even at higher altitude.

The Berkut system was able to launch and guide missile outward to the ring, which meant target which reached minimal engagement distance and already have flown above the SAM ring could not be engaged. The engagement zone was limited by the Yo-Yo antenna system. The engagement zones of adjacent SAM sites (batteries/regiments) were overlapped to make harder breaking through the SAM rings. (



Above are the overlapping engagement zones of regiments.

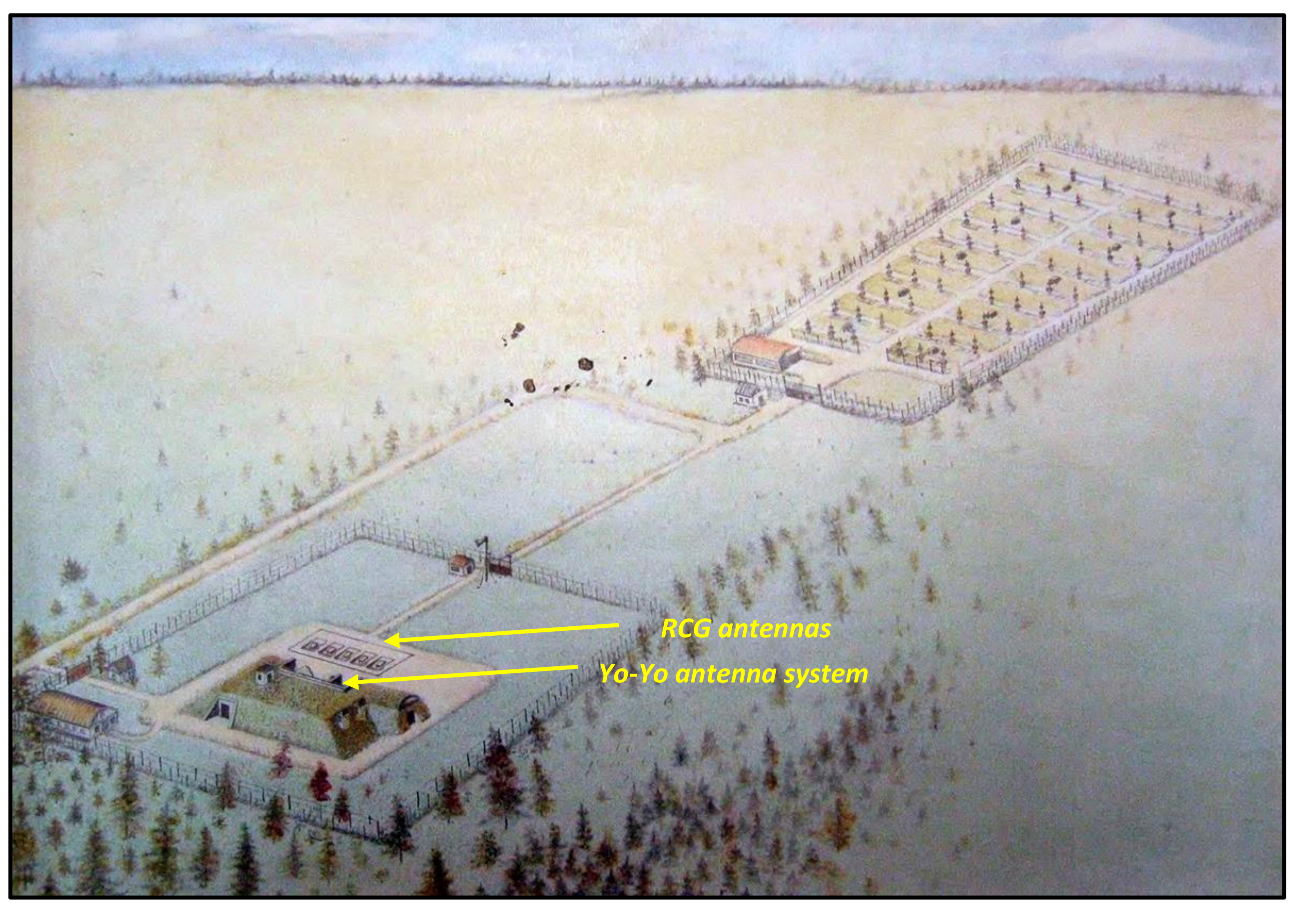
Regardless the Berkut was outdated from many aspects in the middle of ‘70s the system was kept in service until early ‘80s, even in 1982 happened smaller upgrades (S-25R) only two years before the retirement which happened in 1984. In the mid ‘80s Berkut was totally outdated and was not usable against the most advanced low flying cruise missile threats the first line attack weapons system of the US. This means the S-25 system wouldn't make any reasonable cause to keep it after introducing the S-300.



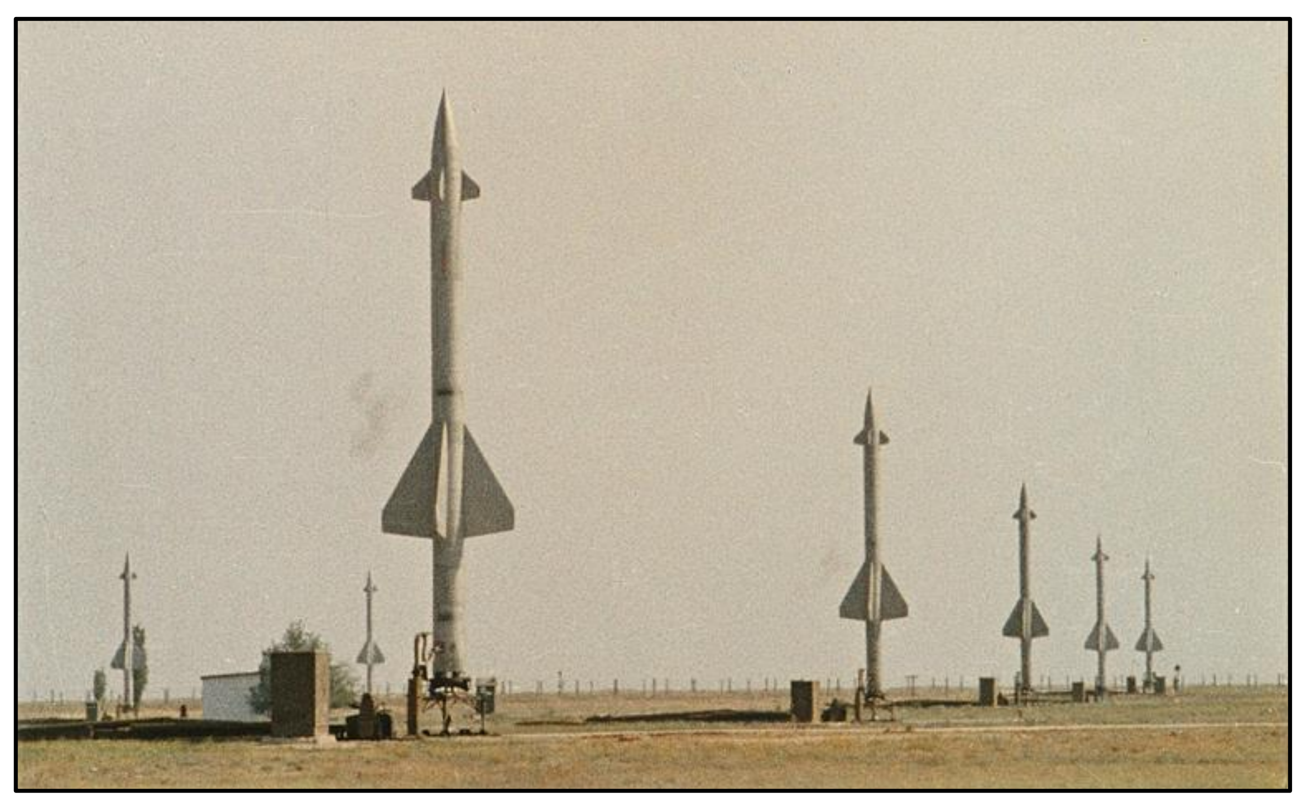
Above is the engagement zone of the S-25 Berkut with different type of missiles during its service against non-maneuvering, without electronic jamming up to 300 m/s target speed. (Target offset distance is 0 km.)

In mid ‘80s the old AGM-28 was not used anymore and it was totally unimaginable that SAC would use B-52s or any other intercontinental bomber with gravitational nuclear bomb. The Berkut simply did not have any target which could deal in ‘80s. Cruise missiles at 30 m altitude were below the minimal engagement altitude of the Berkut.

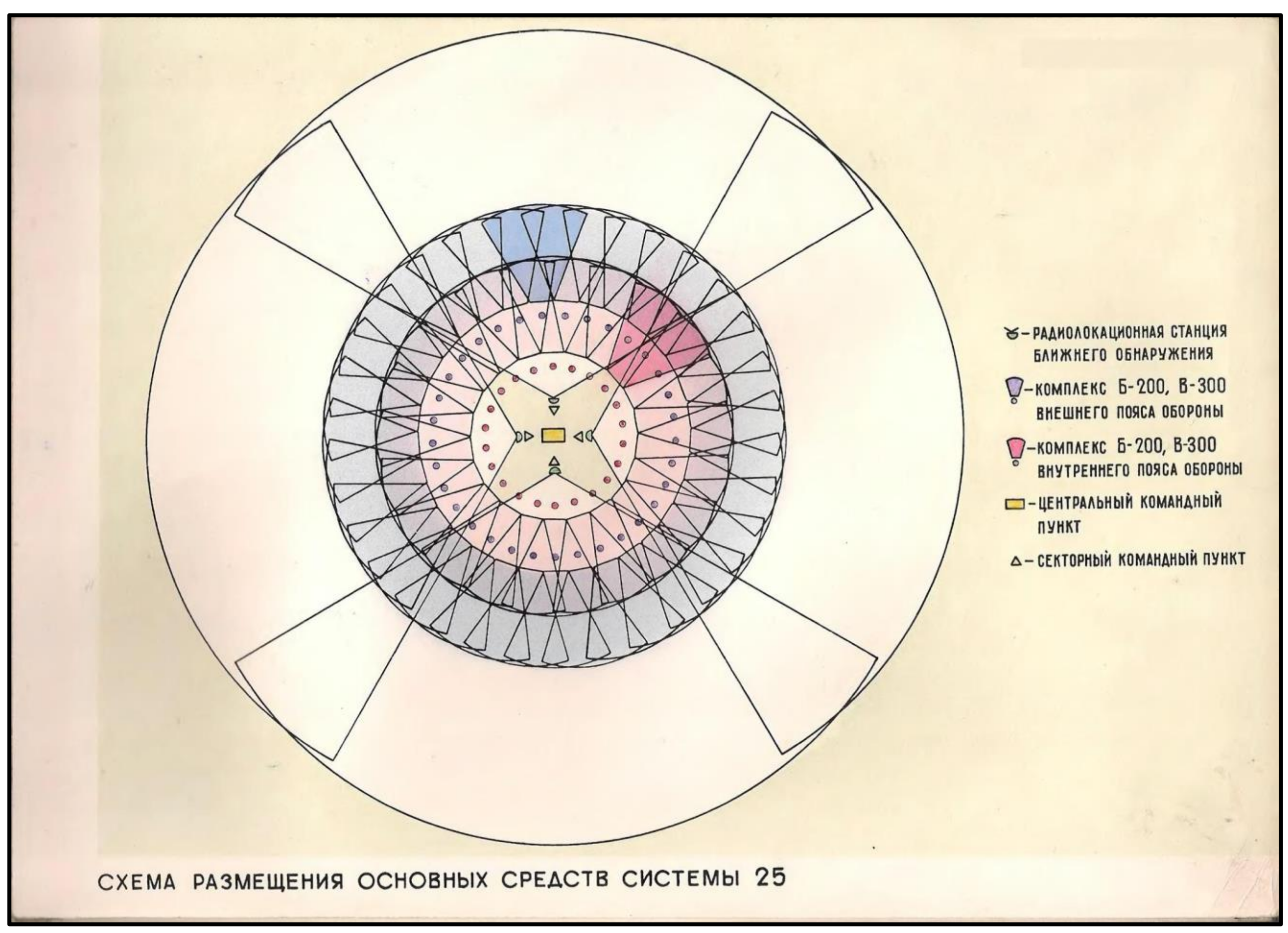
When the S-25 entered into service it was very potent and strong SAM system because of the lots of missiles and target channels but it had its own price. It was so expensive which made obvious the USSR could not afford to just defend all major cities of the Soviet Union, which in some cases simply could not be justified. The later developed SAM system had to be simpler, more flexible and deployable comparing to the totally static Berkut. From this conclusion was developed the SA-75 Dvina and the S-75M Volkhov (SA-2 family) which had only a single target channel per site/battery. SA-2 variants were widely used in conflicts of Cold War.



Above is site of an S-75 Berkut regiment with bunkers, with Yo-Yo radar system (yellow circle) and the missile launch stations.



Missiles are in launch positions.



Above are the missile batteries (regiments) and the range of early warning radars.